South Star Cogeneration LLC is seeking approval from the CEC to construct and operate the South Star Cogeneration Project (South Star) in western Kern County approximately 35 miles southwest of Bakersfield, California. The South Star Project will consist of two substantially identical cogeneration plants, South Star I (Section 17, T32S, R23E) and South Star II (Section 7, T32S, R23E), that are located approximately 1.5 miles apart on contiguous Texaco California Inc. (TCI) property in the South Midway-Sunset Oilfield. The Application for Certification (AFC) presents an evaluation of the entire South Star Project in a manner to clearly indicate the environmental affects associated with each site and its related linear facilities.

South Star I includes the following project components shown on Figure 2-1:

- South Star I site;
- Replacement of poles and conductor for approximately 4.7 miles of existing 12.47 kV transmission line;
- 0.6 mile 115 kV transmission line extension to South Star I site;
- Alternative stand-alone 5.3 mile 115 kV transmission line;
- 3.6 miles of natural gas line (Kern-Mojave to Station 109 and natural gas line placed within TCI South Midway Utility Corridor Segment A);
- Approximately 2.4 mile Alternative Route 1 natural gas line; and
- Improved access road (Midoil Road to South Star I site).

South Star II includes the following project components as shown on Figure 2-1:

- South Star II site;
- 3.8 mile addition of second 115 kV circuit on proposed South Star I transmission line;
- 1.4 miles of natural gas line (placed within TCI South Midway Utility Corridor Segment B);
- Alternative aboveground Route 2 natural gas line; and
- Improved access road (Midoil Road to South Star II site).

The project is located in the foothills of the Coast Ranges (locally the Temblor Range) near the southern end of the San Joaquin Valley, at the limit with the west edge of the Great Valley Physiographic Province of California (Figure 8.15-1). The primary points of geologic interest in the project area are the oil and gas production and seismic activity. Oil and gas have been produced in the area of the project site since 1910. Thirty-four earthquakes exceeding a Richter local magnitude (M_L) 5 have been located within 100 km (63 mi) of the South Star I and II Project sites; the largest event was the 1857 Fort Tejon moment magnitude (**M**) 7.8 earthquake (Ellsworth, 1990).

8.15.1 Affected Environment

8.15.1.1 Regional Geology and Physiography

The proposed South Star I and II sites are on the foothills along the eastern edge of the Coast Ranges Province at the western limit with the Great Valley Province (Figure 8.15-1). Part of the gas line runs into the Great Valley Province. The Coast Ranges Province separates the Great Valley Province from the Pacific Ocean, and extends from the Oregon border south to the Transverse Ranges, a distance of approximately 1000 km (620 mi). The intersection of the Transverse Ranges with the Sierra Nevada creates the southern terminus of the Great Valley. The eastern margin of the Great Valley is bounded by the Sierra Nevada Province (Norris and Webb, 1990). A general description of the geology of the Coast Ranges Province and the Great Valley Province is provided below.

Coast Ranges Province. The Coast Ranges are underlain by uplifted and intensely deformed Upper Jurassic (150 Ma) and younger Franciscan Assemblage rocks which are faulted against the less deformed sedimentary rocks of the Great Valley Group along a deformed regional Late Mesozoic thrust fault. The block situated west of the San Andreas fault is underlain by Late Mesozoic granitic basement. These Mesozoic rocks are overlain by Tertiary and Quaternary marine and non-marine deposits.

Great Valley Province. The Great Valley separates the Coast Ranges to the west from the Sierra Nevada in the east. This province is comprised of two elongate northwest- to southeast-trending basins: the Sacramento Basin to the northwest and the San Joaquin Basin to the southeast. This province is approximately 700 km (435 mi) long and 70 to 90 km (43 to 56 mi) wide, and characterized by a thick, relatively undeformed sequence of alluvium and volcanic deposits. The present-day basin evolved from a late Jurassic to middle Tertiary (40-

150 Ma) marine forearc basin (Dickinson, 1981; Castillo and Zoback, 1994). In the late Tertiary (25-30 Ma), a change in the relative motion between the Pacific and North American plates resulted in the gradual uplift of the Coast Ranges and the eventual isolation of the basin from the ocean. More recent Miocene and lower Pliocene sediments were derived from the neighboring Coast Ranges and the Sierra Nevada (Perkins, 1987). By the late Pliocene (2-3 Ma), subaerial depositional conditions prevailed and Sierra Nevada-derived sediments were deposited in the basins (Bartow, 1987).

8.15.1.2 Regional Seismotectonic Setting and Seismicity

The western margin of the Great Valley is termed the Coast Ranges-Central Valley geomorphic boundary (Wakabayashi and Smith, 1994). This boundary is defined by a system of seismically active folds and thrust faults. Earthquakes associated with this system include the 1983 moment magnitude (**M**) 6.5 Coalinga and the 1985 **M** 6.1 Kettleman Hills events (Bloch *et al.*, 1993; Wakabayashi and Smith, 1994). The Coast Ranges-Great Valley boundary separates the relatively undeformed strata of the Great Valley from the deformed rocks of the Coast Ranges of California. The southeastern margin of Great Valley is defined by a number of short, discontinuous faults, referred to herein as the Kern Front fault system which also marks the western extent of the Sierra Nevada batholith.

Significant Faults. The southern San Joaquin Valley and the Coast Ranges are surrounded by a number of active and potentially active faults, some of which have generated large, damaging earthquakes during historic time (see section Historical Seismicity). There are approximately 30 Quaternary faults within a 100-km-radius (62 mi) of the site (Figure 8.15-2). The most significant of these are listed in Table 8.15-1, along with estimates of the Maximum Credible Earthquakes (MCE). MCE magnitude estimates are based on the Working Group for Northern California Earthquake Potential (1996), Working Group for California Earthquake Probabilities (1995), and empirical relationships amongst fault rupture length, fault rupture area, and maximum magnitude (Wells and Coppersmith, 1994). The most significant Quaternary faults within 100 km (62 mi) of the site are discussed in brief detail below.

San Andreas Fault. The San Andreas fault is the main, active, crustal discontinuity separating the northwest-moving Pacific plate from the southeast-moving North

American plate. This right-lateral strike-slip fault extends from the Gulf of California in Mexico northwestward along the western edge of California through the Coast Ranges, before heading offshore and running parallel to the coast to north of San Francisco Bay, and finally terminating near Cape Mendocino. The fault is divided into several rupture segments, based on differing structural, geomorphic, and seismic characteristics along the fault. The three fault segments nearest to the site are the Mojave, Carrizo, and Cholame segments (Figure 8.15-2). Simultaneous rupture of all three of these fault segments, with a fault length of approximately 315 km (196 mi), would generate an earthquake of **M** 8. The 1857 **M** 7.8 Fort Tejon earthquake ruptured these fault segments and parts of neighboring segments between the Coachella Valley and San Benito. From empirical relationships between fault length and earthquake magnitude (Wells and Coppersmith, 1994), the Mojave, Carrizo, and Cholame fault segments have calculated maximum earthquakes of **M** 7.5, 7.6, and 7.2, respectively. A **M** 8 earthquake comparable to the 1857 event is the San Andrea fault (Table 8.15-1). These closest segment to the site area is the Carrizo segment, located 11 km (7 mi) to the southwest of the site (Figure 8.15-2).

San Juan Fault. The San Juan fault zone plays from the San Andreas just to the north of Cholame (Figure 8.15-2). This right-lateral, strike-slip fault is approximately 86-km-long (53 mi), running along the western side of the Carrizo plain, at the foot of the La Panza Range. The fault is a broad, complex zone of *en echelon* fault strands. The northern extent of this fault, namely the Red Hills and Gillis Canyon faults, have ruptured during Holocene time (Jennings, 1994). Although only the northern part of this fault zone displays evidence for recent activity, in the absence of detailed geologic or paleoseismic data, we conservatively assume that the entire fault zone is active and is capable of generating a MCE of **M** 7¼. The San Juan fault zone is located approximately 40 km (25 mi) west-northwest of the site (Figure 8.15-2).

La Panza Thrust. The La Panza thrust is a northwest-striking, northeast-dipping reverse fault along the southwestern margin of the La Panza Range (Figure 8.15-2). Jennings (1994) depicts the La Panza thrust as being Quaternary in age, i.e., it cuts Pleistocene deposits. The fault is approximately 71-km-long (44 mi) and consists of two sections, a 38-km-long (24 mi) southeast and 33-km-long (21 mi) northwest section, separated by a prominent right bend. There are no paleoseismic data to indicate timing of recent movement on the La Panza thrust, therefore we assume that the entire fault ruptures at once, generating a MCE of M 7¼. The La Panza thrust is located approximately 40 km (25 mi) to the west of the site (Figure 8.15-2).

South Cuyama Thrust. The South Cuyama fault is a northwest-striking, southwest-dipping thrust or reverse-oblique fault located 80 km (50 mi) to the west-southwest of the site (Figure 8.15-2). Jennings (1994) shows this to be Quaternary in age. Rupture of the South Cuyama fault would generate a MCE of M 7¼.

Big Pine Fault. The Big Pine fault is a 32-km-long (20 mi), west-southwest-striking, left-lateral strike-slip fault that merges with the San Andreas and Garlock faults at Frazer Mountain (Figure 8.15-2). Jennings (1994) indicates that the fault has both left-lateral and down-to-the-north offset. Only the easternmost part of the fault appears to have been active during the Late Quaternary. The Big Pine fault is located approximately 55 km (34 mi) south of the site and has a MCE of M 6.8.

Santa Ynez Fault. The Santa Ynez fault extends east-west from the coast near Point Conception, across the entire width of the Transverse Ranges (Figure 8.15-2). Total fault length is over 150 km. This south-dipping thrust fault is divided into western and eastern segments. The western segment shows some evidence of Holocene movement (Jennings, 1994). The eastern segment extends from Gibraltar Reservoir, north of Santa Barbara, to Agua Blanca Creek and is located 74 km (46 mi) south of the site (Figure 8.15-2). The eastern segment is approximately 70-km-long (43 mi) and has been active during Quaternary time (Jennings, 1994). This fault has a MCE of M 7.3.

Pine Mountain Fault. The Pine Mountain fault is a 47-km-long (29 mi) west-northwest-striking fault that links the Santa Ynez and Big Pine faults (Figure 8.15-.2). This is a north-dipping thrust fault that shows evidence for movement during Quaternary time. The Pine Mountain fault is located about 75 km (47 mi) south of the site and has a MCE of **M** 7.0.

Frazer Mountain Thrust (Dry Creek Fault & Alamo Thrusts). The Frazer Mountain thrust is one of a series of north-dipping, east-northeast-striking thrust faults located to the south of the junction between the San Andreas and Garlock faults. Jennings (1994) indicates that these faults have been active during the Quaternary. The closest thrust fault is located approximately 63 to 76 km (30 to 47 mi) south of the site (Figure 8.15-2). The MCE, based on approximate rupture length, for these faults is **M** 6.4.

San Gabriel Fault. The San Gabriel fault is a northwest-striking, right-lateral strike-slip fault that extends from Frazer Mountain to Cajon Pass, for a distance of approximately 106 km (66 mi). Jennings (1994) only shows a short section of the fault near Saugus as having Holocene activity, and only the northern 70 km (43 mi) as being active in the late Quaternary. Assuming that this represents the maximum rupture length for the fault, the MCE is M 7.0 (Table 8.15-1). The San Gabriel fault is located 75 km (47 mi) south of the site (Figure 8.15-2).

Clearwater Fault. The Clearwater fault is a 32-km-long (20 mi), west-northwest-striking thrust fault between Pyramid Lake and Bouquet Reservoir (Figure 8.15-2). The fault dips to the north and shows evidence for movement during Quaternary time. It is located approximately 10 km (6.2 mi) south of the Mojave segment of the San Andreas fault and therefore may not be an independent earthquake source. It may only rupture when there is a large earthquake on this part of the San Andreas. If it does rupture as an independent source, then it has the potential to generate a MCE of **M** 6.8.

San Cayetano/Santa Ana Fault. The San Cayetano fault is a Holocene-active, north-dipping thrust located 100 km (62 mi) to the south of the site (Figure 8.15-2). It is approximately 40-km-long (25 mi) and has a MCE of **M** 7.

Garlock Fault. The 250-km-long (155 mi) Garlock fault is a major southwest-northeast-striking active fault that marks the boundary between the Sierra Nevada and Mojave Block seismotectonic provinces (Figure 8.15-2). This fault extends from its junction with the San Andreas fault at Frazer Mountain, across the southern margin of the Sierra Nevada. At its eastern end, the fault separates the Basin and Range Province and Mojave Block. This fault is located 59 km (37 mi) southeast of site and is divided into western and eastern segments (Working Group for California Earthquake Probabilities, 1995). The western segment, closest to the site is considered capable of generating a MCE of **M** 7.

Coast Range-Sierran Block Boundary Zone. The Coast Range-Sierran Block (CRSB) is a complex zone of thrust faulting that marks the boundary between the Coast Range block and the Sierran basement rocks that are concealed beneath the Great Valley sedimentary rocks of the San Joaquin Valley (Figure 8.15-2). This is a complex array of west-dipping thrusts and east-dipping back-thrusts. The CRSB extends for over 500 km, from near Red Bluff in the northern Sacramento Valley to Wheeler Ridge in the southern San Joaquin Valley (Wakabayashi and Smith 1994; Wong et al., 1988). The CRSB was the probable source of the 1892 M 6¼ to 6½ Winters earthquakes and the 1983 M 6.5 Coalinga earthquake (Wong et al., 1988). Although the faults themselves do not rupture to the surface, the CRSB is marked along much of its length by an alignment of fault-propagation folds that form a series of low hills along the western side of the Sacramento and San Joaquin valleys. The closest segment of the CRSB to the site, the Kettleman Hills south dome and the Lost Hills faults, are located respectively approximately 74 km (46 mi), and 12 km (7.5 miles) to the northwest and are capable of generating a MCE of M 6.8 (Wakabayashi and Smith 1994) (Figure 8.15-2, Table 8.15-1).

Buena Vista Fault. The Buena Vista fault is a small west-northwest-striking fault located along the southwestern margin of the San Joaquin Valley (Figure 8.15-2). This fault has displayed creep during historic time. As recent movement on this fault has been associated with fluid removal and not tectonic activity, it is not considered to pose a potential seismic hazard. The fault is located approximately 10 km (6.2 mi) northeast of the site.

Kern Front Faults. Immediately north and west of Bakersfield are a series of north- and northwest-striking faults with apparent normal, down-to-the-west displacement (Figure 8.15-2). These faults mark the boundary between the sedimentary rocks of the San Joaquin Valley and the granitic rocks of the Sierra Nevada. A number of these faults, including the Pond-Poso, Kern Front, New Hope, and Premier faults are either actively creeping or have experienced creep during historic time as a result of aquifer collapse due to groundwater removal (Holzer, 1980). Several of these faults, including the Mt. Poso, Poso

Creek, Jewett, and Kern Gorge faults all offset Quaternary deposits. The exact age of fault movement is unknown. Several of these faults experienced ground breaks during the 1952 **M** 7.3 Arvin-Tehachapi earthquake on the White Wolf fault (Jennings, 1994). The relatively short length of these faults indicates that each is probably only capable of generating a MCE of **M** 6.5 (Table 8.15-1).

Tehachapi Front. The southern end of the San Joaquin Valley is marked by a complex zone of deformation involving both thrust faulting and oblique-reverse faulting (Figure 8.15-2). This region includes the White Wolf fault, considered to be the source of the 1952 Arvin-Tehachapi earthquake. This earthquake produced about 60 km (37 mi) of surface rupture along the White Wolf fault and a number of smaller offsets on several of the Kern Front faults. This sequence of south- to south-southeast-dipping reverse and reverse-oblique faults includes the Wheeler Ridge and Plieto thrusts in the southwest and the White Wolf and Springs faults in the northeast. Geodetic modeling indicates that left-lateral faulting appears to be dominant in the southwest and reverse faulting becomes more prevalent to the northeast (Bawden, 2001). The 1952 earthquake shows that this zone of faulting is capable of generating large, damaging earthquakes. The MCE for the White Wolf fault is considered to be **M** 7.4 (Working Group for California Earthquake Probabilities, 1995).

Historical Seismicity. The historical earthquake record for the southern San Joaquin Valley probably extends back to the mid-1800's (Toppazada et al., 1981). Until adequate seismographic coverage came into existence in southern California in the 1930's through the efforts of California Institute of Technology (CIT), earthquake detection was generally limited to those events which produced felt or physical effects. Earthquakes as small as Richter local magnitude (M_L) 3 were probably not completely observed throughout the San Joaquin Valley until about 1960. Thereafter, due to efforts by CIT and the USGS, seismographic coverage in southern California improved significantly, and currently earthquakes as low as M_L 2.0 to 2.5 can be detected for most portions of the San Joaquin Valley.

The site is located near the southeastern termination of the southern San Joaquin Valley, an area which has historically been seismically active. The largest historical earthquakes have generally occurred along the valley margins. A historical catalog was compiled for the study region and the epicentral locations are shown on Figure 8.15-2. The study region encloses an area approximately 100 km (62 mi) in radius from the site and includes all seismic sources which may generate potential strong ground shaking.

The catalog was compiled from the following data sources: the National Earthquake Information Center's Preliminary Determination of Epicenters; Stover, Reagor, and Algermission's U.S. historical catalog; the catalog of the California Division of Mines and Geology, 1735-1974; the catalog of the Decade of North American Geology (DNAG); and the Northern California Seismic Network and the Southern California Earthquake Center catalogs. The resulting catalog (1852-2000) consists of nearly 1700 earthquakes of approximate M_L 3 and greater (Figure 8.15-2).

Patterns of seismicity in the region generally correspond to Quaternary faults (e.g., White Wolf, Wheeler Ridge) (Figure 8.15-2). The only exception may be a linear band of seismicity about 50 km (31 mi) east of Bakersfield that runs north-south and does not appear to be associated with any active Quaternary fault. This zone is referred to as the Southern Sierra Nevada seismic zone by Jones and Dollar (1986). Diffuse seismicity is interspersed among faults south of the intersection of the San Andreas and Garlock faults.

Significant Earthquakes. Fifteen earthquakes of estimated ML 6.0 or greater have occurred within 100 km (62 mi) of the site location historical times. Some of these events are annotated on Figure 8.15-2, and the two significant ones are discussed in more detail below. The closest earthquake to the site (~6.5 km, 4 mi) occurred on 9 June 1928 and measured ML 4.0 in size (Figure 8.15-2).

1857 Fort Tejon Earthquake. At around 8:00 am (PST) on 9 January 1857, the largest earthquake within the study region ruptured the San Bernardino, Mojave, Carrizo, and Cholame segments of the San Andreas fault (Figure 8.15-2). Several estimates of the size of the earthquake have been made. A surface wave magnitude (M_s) 8¼ has been estimated for the event based on the rupture length, average slip, and based on comparison to the 1906 earthquake in northern California (Sieh, 1978). The currently accepted estimate for the event is **M** 7.8 (Ellsworth, 1990). The epicenter of the earthquake is located near Fort Tejon (Real *et al.*, 1978), approximately 72 km (45 mi) west-southwest of the site. Fort Tejon was destroyed (maximum Modified Mercalli Intensity [MMI] IX) (Table 8.15-2) and the effects were felt over an area of at least 350,000 km^2 (Townley and Allen, 1939). The site likely experienced a MMI of VII-IX (Stover and Coffman, 1993). Instances of fissuring, sandblows, and hydrologic changes were reported from Sacramento to the Colorado River delta. One report describes liquefaction in the region between Stockton and Sacramento (Stover and Coffman, 1993). Reported surface rupture extended over a distance of 230 km (143 mi), possibly as great as 360 km (224 mi), from San Bernardino to San Benito County. Offset channels and alluvial deposits are evidence of at least 6 m (20 ft) of right-lateral slip during the 1857 event (Grant and Sieh, 1993).

1952 Kern County Earthquake (Arvin Tehachapi). The 1952 Arvin-Tehachapi earthquake occurred on 21 July at 3:52 pm (PST) on the White Wolf fault zone, north of the junction of the San Andreas and Garlock fault zones (Ellsworth, 1990; Bawden, 2001; Figure 8.15-2). The earthquake ruptured 60 km (37 mi) of the White Wolf fault, and was the largest in the conterminous United States since the 1906 San Francisco earthquake (Bawden, 2001). It claimed 12 lives and caused property damage estimated at $60 million (Stover and Coffman, 1993). The magnitude of this event was **M** 7.3 (MMI XI). Over a two-month period, 188 aftershocks of M_L 4.0 and higher were recorded and six of these were greater than M_L 5. The mainshock epicenter was approximately 40 km (25 mi) south of Bakersfield. Aftershocks were generally concentrated around the northern termination of the White Wolf fault zone (Richter, 1955).

Property damage was significant in Bakersfield, due to both the intensity (MMI VIII) and number of large-magnitude aftershocks. The Southern Pacific Railroad sustained major damage (MMI XI) to railroad tracks and tunnels where it crossed the fault zone. Ground shaking was felt over a 419,200 km^2 area. Abundant surface rupture fractures were noted along the lower slopes of Bear Mountain, along the White Wolf fault zone (Stover and Coffman, 1993; Warne, 1955). The alluvium in the valley was erratically cracked. Reports of long-period wave effects from the earthquake were widespread, and nonstructural damage occurred to tall buildings in Los Angeles.

8.15.1.3 Local Geology

The South Star I and II Project area is located in western Kern County adjacent to the settlement of Fellows (see Figures 1-1 and 2-1). The topography within the Fellows-Midway District consists of a series of low, dissected, foothills that form the pediment of the adjacent Temblor Range. At the base of the foothill area, a flat-lying, alluvial valley (Midway Valley) trends northwest - southeast and encompasses the settlements of Taft, Fellows, Midway, and Derby Acres. The topography from the crest of the Elk Hills to the Buttonwillow District represents a broad, slightly inclined plain. To the east, the Elk Hills form a prominent, erosion resistant landform. Its eastern margin gradually descends in elevation towards Buena Vista Lake and merges with the Kern River floodplain. The project area is also includes portions of the Midway-Sunset, and Fellows oil and gas fields.

Most of the South Star I and II facilities are located in an area constituted by low hills on the foot of the Temblor Range, with average gradient slopes of 20-30% to the northeast. The South Star I and II plant sites are located at an approximate elevation of 1,500-1,600 ft and 1,650-1,750 ft above mean sea level, respectively. Part of the gas line intercepting the Midway Road and Highway 33 runs in a flat area within the valley from an elevation of 365.8 m msl (1,200 ft) at the TCI Station 109 gas dehydration plant to an elevation of 281.9 m msl (925 ft) at the intersection with the Kern-Mojave gas pipeline. Local drainage is directed towards Broad Creek, except for the northern part of the power line, for which the drainage flows towards Buena Vista Creek. Drainage is made through small creeks created by erosion during seasonal run-off of water. All headwaters in the area originate in the Temblor Range.

Structure. Despite the flat topography of the southern San Joaquin Valley, the subsurface geology is structurally complex with a number of folds and faults. The overall structure beneath the southern San Joaquin Valley is an asymmetric syncline (Figure 8.15-3). The axis of this fold is approximately parallel to the valley axis. The western limb of this fold where the site is located is considerably steeper than the eastern limb. Within this major fold are many smaller folds and several faults. These structures act as oil and gas traps that support a thriving petroleum industry.

Stratigraphy. Figure 8.15-4 presents the general stratigraphic column in the project area. The geological map in the area of concern at a 1:24 000 scale is presented in Figure 8.15-5. Information was compiled from geological maps in Dibblee (1971) and CDMG (1964).

Sedimentary rocks in the locality of the site range in age from late Mesozoic to Holocene (140 Ma to 10 ka) (Figure 8.15-5). The majority of the area is underlain by Quaternary (0-2 Ma) alluvium, which overlies a series of sandstones and shales which represent the filling of a marine basin. Also represented by this sequence is the transition from a marine to a lacustrine and deltaic environment. The sequence was subsequently capped by coalescing alluvial fan deposits. The southern San Joaquin Valley contains in excess of 7,600 m (25,000 ft) of post-Cretaceous sediment in the Tejon basin, southwest of Bakersfield. This region is a major source of oil. The following is a brief description of the lithologies of the stratigraphic column at the site, from oldest to youngest.

The study region is ultimately underlain by the Mesozoic crystalline basement of the Sierra Nevada block (Figure 18.15-5). This folded and faulted Mesozoic basement is overlain by a sequence of upper Jurassic to Quaternary sedimentary rocks, commonly called the Great Valley Sequence. This is essentially a thick succession of marine shales with interbedded greywacke. These clastic deposits were derived from a source to the east, as they lack any granitic detritus that would indicate a Salinian origin (Page, 1986). In addition to these marine deposits, the lower part of the Great Valley Group contains basaltic pillow lavas, breccias, and volcanoclastic deposits in some localities. This sequence is generally found at a depth of approximately 6,400 m (21,000 ft) in the San Joaquin Valley (Bloch *et al.*, 1993).

Above the Great Valley Group is the Lower Tertiary sequence, comprised of siliceous to calcareous shales and sandstones representing deep marine, continental shelf, and possibly deltaic depositional environments (Medwedeff, 1989) (Figure 8.15-5). The transition from marine to terrestrial deposition occurred during the Pliocene (2-5 Ma). Lower Pliocene rocks are shallow marine, while overlying, younger formations tend to be consistent with a brackish-water paleoenvironment. Fluvial and lacustrine siltstones, sandstones, and conglomerates are typical of sedimentary layers deposited during the Pliocene to Pleistocene.

Surficial sedimentary units ranging from the upper Miocene, Plio-Pleistocene to Recent age underlie the entire project area. The geologic units at the surface near the South Star Project sites and along the linear line routes are the Santa Margarita and Monterey Shale Formation (undifferentiated on Figure 8.15-7, and shown as *Tsm*), Tulare Formation (*QTtl* on Figure 8.15-7), and Quaternary Alluvium (*Qa*l on Figure 8.15-7). The Santa Margarita-Monterey shale Formation consists of approximately 396 m (1300 ft) of interbedded white poor consolidated sandstone and shale, with local very coarse conglomerate and granitic breccia deposited during the Upper Miocene (Dibblee, 1971). The Tulare Formation consists of alluvia fan deposits made of beds of poorly consolidated alternating sand and gravel with lenticular gypsiferous deposits, clays and silty clays. This formation was deposited during the Pleistocene between approximately one million and 11,000 years ago, and has an estimated thickness ranging from 670 to 850 m (2,200 to 2,800 ft) (Harden, 1998). It was deposited in the large basin formed between the Sierra Nevada and Coast Ranges. Within approximately the last 10,000 years, the Tulare Formation and older rocks in the Temblor, San Emigdio, and Tehachapi ranges and in the Elk Hills have been eroded and redeposited to form the Quaternary alluvium that is blanketing the bottom of the San Joaquin Valley and portions of the foothills. Quaternary age undifferentiated alluvium unit is designated as *Qal* on Figure 8.15-7. This geologic units range from stream, terrace, fluvial, and alluvial fan and floodplain deposits, and consists in unconsolidated gravels, sands, silts, and clays.

The specific unit encountered between each facility of the South Star Project sites are presented below:

South Star I Cogeneration Plant Site. The proposed South Star I Cogeneration Plant site is located in the southeast quarter of Section 17, T32S, R23E. The plant will be located within a 6.3 acre fenced area within a 20 acre parcel (1000-feet square), but only a portion of this area actually would be used for the plant. An electrical switchyard, access spur road, parking areas and laydown areas also would be included within this plant area. There are a number of existing roads and roadcuts on the site, but the site consists primarily of steep, open grassland. Substantial grading and filling would be required to create a level platform for use of this site.

The proposed site is located on a grassy hilltop near the western edge of this portion of the oil field. No exposed bedrock was noted; however, the very steep hill at the north side of the site drops precipitously into a deep drainage, with an exposed sandy bottom. A maze of road cuts crosses the top of the site, and several deep cuts run around the hillside, but there is little actual development on the site. The proposed plant site is located entirely within the *QTtl* unit.

South Star I Proposed Electrical Transmission Line. South Star proposes to replace an existing 12.47 kV electrical transmission line with a 115 kV transmission line, from the Morgan Substation to the South Star I plant site. To the extent feasible, existing poles would be reused. The existing transmission line runs through the hills to the west of the principal area of oil field development for the most part. There is some evidence of older oil development in this area, including scattered oil wells and pipelines, and a few abandoned facilities, but much of the area is grassland which has been subject to cattle grazing fairly recently. The existing line begins at the Morgan Substation, which is located immediately east of Mocal Road, at a point about 2.5 miles northwest of the town of Fellows. The line then parallels the southwest side of Mocal Road and runs southeast for a few hundred feet; then turns and continues due south up along a ridgeline and through rolling hills for about a mile. At this point the line turns southeast, and continues in this direction for about three miles to a hilltop near the western boundary of Section 17, in a western extension of the active TCI Midway-Sunset Oilfield, above and to the west of the proposed South Star I plant site. The existing line would be replaced to this point, a distance of about 4.7 miles. From this point, a new 115 kV line would be constructed on a route extending east, then southeast to the South Star I plant site, a distance of about 0.6 miles.

The portion of the transmission route from South Star II to Morgan Substation is generally within the *Qal* unit in the topographic low areas (drainages) and within the *QTtl* and *Tsm* units in the topographic high areas (ridges and hilltops). The route between South Star I and South Star II is within the *QTtl* unit.

South Star I Proposed Natural Gas Pipeline Route. The proposed route for the natural gas pipeline would extend from a tie-in to the existing Kern-Mojave Pipeline at Midway Road, about 2.5 miles east of the town of Fellows, southeastward about 3 miles to TCI's Station 109 gas dehydration plant, in the southwest quarter of Section 9, T32S, R23E. Vegetation in this area included occasionally dense thickets of saltbrush and other arid chaparral species as well as low sparse grasses; however, ground visibility generally was good. Soils are sandy, and low grade cherts are common on the surface. The proposed natural gas pipeline route is almost entirely within the *Qal* geologic unit. Only a small portion of the route crosses the *QTtl* geologic unit near the Station 109 plant.

South Star I Alternate Natural Gas Pipeline. An alternate route for the natural gas line begins at the Kern-Mojave Pipeline tie-in described above. The route then runs due south to intersect an existing surface wastewater line, which it follows southeast to the same end point as the proposed route at Station 109. Between Midway Road and State Route 33 the alternate route lies southeast of the proposed route. A short distance northeast of State Route 33, the alternate makes a turn to the west, crosses the proposed route, parallels the west side of the proposed route, then turns south to join the proposed route at TCI's Station 109 gas dehydration plant. From this point, the alternate route shares the same alignment as the proposed route to its terminus at the South Star I plant site. This route is also almost entirely within the *Qal* geologic unit except for a small portion within the *QTtl* unit near the Station 109 plant.

South Star I Proposed Natural Gas Pipeline, Segment A. This gas pipeline segment would be an above-ground pipeline, mounted on existing piperacks in the existing TCI South Midway Utility Corridor. Segment A would extend southwest from Station 109 to a point a short distance northwest of the South Star I plant site, then would turn sharply southeast to enter the plant site. Use of this gas line route is dependent upon construction of the proposed or alternate route from the Kern-Mojave tie-in. The entire alignment runs through developed and active oil fields and is within the *QTtl* geologic unit.

South Star II Cogeneration Plant Site. The proposed South Star II Cogeneration Plant site is located in the center of Section 7, T. 32 S, R. 23 E. The size, conformation and use of the plant would be essentially similar to the South Star I Plant site. The proposed site is located on a hillside at the head of a small drainage, with extensive oil field development to the south and east and relatively undeveloped open grazing lands a short distance to the north. Some grading and filling would be required to create a level platform for use of this site. The site is entirely within the *QTtl* unit.

South Star II Proposed Natural Gas Pipeline Segment B. A 1.4 mile natural gas pipeline would originate at the proposed South Star I pipeline Segment A, about 1.25 miles southwest of Station 109. From that point, Segment B would extend northwest about 1.4 miles to the South Star II plant site. The line would be above ground, and would use existing piperacks in the TCI South Midway Utility Corridor. The line is within the *QTtl* geologic unit.

South Star II Alternate Natural Gas Pipeline. This alternate route for natural gas would extend from a tie-in to the terminus of the existing TCI North Utility Corridor near Fellows, then approximately follow an existing road southeast, to the proposed South Star II Cogeneration Plant. The survey corridor for this line extended 225 feet to either side of the existing road, with potential siting of the line to either side of the existing road on an aboveground pipe rack. Some grading and filling would be required at a few locations to accommodate a new line. This line is entirely within the *QTtl* geologic unit.

Surficial Soils. Except for the proposed and alternate routes for natural gas, almost the entire project facilities are underlain by the Pyxo-Cochora and Pyxo-Cochora-Badlands association consisting of loam, and gravelly loam, shallow, well drained and have low to very low available water capacity. The soils of this association are encountered at the shoulder slopes and backslopes (15-50% percent slope). In steep slopes (50-70%), this soil consists of very steep barren land dissected by many intermittent drainage channels where runoff can be very rapid. Because shallow depth and local steepness of slope, this soil association is subject to very severe erosion. The proposed and alternate gas line route are underlain by the Welport-Elkhills soil association and the Guijarral complex. The Welport-Elkhills association consists of shallow gravelly sandy loam, well drained, slopes between 9 to 30%, with severe to moderate water and wind erosion susceptibility. The Guijarral gravelly sandy loam with slopes ranging from 2 to 9 % and has a slight and moderate water and wind erosion susceptibility (see Section 8.9 on Agriculture and Soils).

Hydrogeology. The South Star I and II Project sites are located at the limit with the southwestern portion of the San Joaquin Groundwater basin, which is the largest groundwater basin in California covering approximately 35,000 m^2 (13,500 square miles), in the subregion called the Tulare Basin (USGS, 2000b).

The Tulare Basin consists in a thick sequence of approximately 9,800 m (32,000 ft) consisting of alluvial fan deposits semi-consolidated to unconsolidated of the Plio-Pleistocene Tulare formation and recent alluvium, overlying older and consolidated crystalline basement and marine formations. The Tulare formation consists of sands, silts, and clays. The water-producing portion of the groundwater basin is within the upper sections of these deposits and overlying alluvium. The groundwater basin in the project area is considered unconfined (USGS, 2000b); however, the heterogeneity of the alluvial fan complex results in thin, discontinuous lenses of clay that may create isolated perched water systems (USGSb, 2000).

In the general vicinity of the project, the groundwater is encountered at depths in excess of 300 feet below ground surface (USGS, 2000b). In general, the groundwater resource in the area is not used for irrigation or municipal needs because of oil production in the area, resulting consequently the groundwater is of poor quality. The area has been used for oil production for approximately 100 years, and production water/brine has been re-injected into the subsurface during much of that period. The groundwater in the area has very high concentrations of selenium, boron, chlorides, and total dissolved solids (USGS, 2000b).

8.15.1.4 Resources of Recreational, Commercial, or Scientific Value

No information was found indicating that the South Star I and II Project sites will adversely affect geologic resources of recreational, commercial, or scientific value. At the South Star I and II Project sites and along the transmission line, the geologic units at the surface and subsurface are alluvial deposits that are widespread throughout the southwestern part of the San Joaquin Valley; they are not unique in terms of recreational, scientific or commercial value. The potential for rare mineral or fossil occurrences is very low (see Paleontologic Resources in Section 8.16). Furthermore, the South Star I and II Project sites are in the vicinity of intensive oilfield development, and the preferred transmission line route is close to or within rights-of-way of roads, other utilities, and pipelines. Therefore, there is little chance that there are undiscovered near-surface resources that would be adversely affected by the construction.

The South Star I and II Project sites are located at the southeast extent of the Midway-Sunset Oilfield. The Midway Sunset Oilfield represents the principal geologic resource for the project. The field covers approximately 127 km^2 (31,500 acres), extends from 8 km (5 mi) northwest of Fellows to 14 km (9 mi) southeast of Taft roughly paralleling Highway 33 in a northwest-southeast direction. The field produces oil from average depths of 700-1,700 m (2,300 to 5,500 ft) below surface. Its cumulative oil production in 1999 reached 2.54 billion barrels, making it the top California field in total production (CDOG, 1999, 2001). The South Star I and II Project sites will not adversely affect the commercial or scientific value of any oil production. If further economic oil or natural gas reserves were discovered at a later date, the reserves could be tapped by directional drilling even if they existed directly beneath the electrical transmission line. Furthermore, one purpose of the project is to produce steam to enhance recovery of high gravity oils from the oil-bearing rocks. Therefore, the project has potential to increase the commercial values of geologic resources.

8.15.2 Geologic Effects and Hazards

No geologic hazards were identified for any part of the project that would preclude construction. However, there are geologic hazards that must be considered in final design and construction.

8.15.2.1 Ground Rupture

Surface fault rupture occurs when an active fault intercepts and offsets the earth's surface. The State of California delineates zones around active faults under the Alquist-Priolo (AP) Earthquake Fault Zone Act (Hart, 1994) in order to mitigate for the effects of surface faulting. The closest fault zone to the site zoned under the AP Earthquake Fault Zone Act is the San Andreas fault at a distance of approximately 10 km (6.2 mi). No active (Holocene) or potentially active (Late Quaternary) faults were found to cross the plant site in this review (Jennings, 1994). The closest mapped fault (Dibblee, 1971) is located approximately 5.3 km (3.3 mi) southwest of the project area (from the South Star I and II plants) and is named the Recruit Pass fault (Figure 8.15-6), this fault is considered not active or potentially active (Jennings, 1994). The hazard from ground rupture is considered to be low.

According to the Kern County Zoning Map (see Section 8.4, Land Use), Sections 5, 8, and 16 on Figure 8.15-3 (sheet 2) are defined as having a geological hazard. Neither of the South Star I and II plant sites crosses the Sections, even though the TC1 South Midway Utility Corridor (Segment A) crosses the edge of Sections 8 and 16. According to a personal communication with the Kern County Planning Department (Nelson, 2001), the only geological hazard mapped in the Fellows area is a seismic hazard defined in the Kern County Seismic Hazard Atlas prepared for the Kern Council Government (1975).

8.15.2.2 Earthquake Ground Shaking

Strong earthquake ground shaking is probably the most significant seismic hazard that can be expected in the project area. The site has experienced strong ground motions in the past and will do so again in the future. Possibly the strongest shaking that has been observed at the site occurred during the 1857 **M** 7.8 Fort Tejon and the 1952 **M** 7.3 Arvin-Tehachapi earthquakes, where the maximum intensities were MMI VII-IX (Stover and Coffman, 1993).

Within 100 km (62 mi) of the South Star I and II Project sites, there are four identified fault zones, in addition to the San Andreas fault zone, that are considered active. An active fault is defined as having had movement along its trace at least once during the last 11,000 years. The identified faults are shown in Figure 8.15-2 and listed in Table 8.15-1 with an estimate of the MCE. To estimate the maximum shaking that might occur at the plant area in a future earthquake, median estimates of the ground motion parameter, peak horizontal acceleration (PGA), were made using four empirical attenuation relationships and the maximum earthquakes listed in Table 8.15-1. The highest peak value, assuming deep soil conditions at the plant area, is expected to occur from a **M** 8 earthquake at a distance of about 7 km (4.3 mi) occurring on the San Andreas Front fault. Such an event would result in a median PGA of 0.43 g (43% of the acceleration under the force of gravity). In addition to potential earthquakes from the five identified fault zones, there is potential for earthquake activity along unidentified thrust faults east of the San Andreas fault zone . Low-angle thrust faults that cannot be identified by surface ruptures, also known as blind thrusts, have been the foci of recent earthquakes in Southern California (see Section on Historical Seismicity within Section 8.15.1.2). Evidence of a blind thrust beneath the Elk Hills anticline was a M_L 3.0 earthquake recorded as an aftershock of the Coalinga earthquake; its focus was approximately 24 km (15 mi) to the northeast of the South Star I and II Project sites and 8 km (5 mi) below surface (Eaton, 1990).

Probabilistic ground motions, measured in g's at each plant site and along the linear corridors were obtained from the National Hazard Maps developed by U.S. Geological Survey (Frankel et al., 1996). PGA's with a 10% probability of exceedance within 50 years (return period of about 500 yrs) are presented in Table 8.15-3. Values for the sites are 0.57 g for South Star I and 0.40g for South Star II. The PGA values for transmission line and natural gas lines range between 0.4 and 0.57g. The higher ground motion values obtained are a result of the facility's proximity to the San Andreas fault zone. However, these ground motions are for a soft rock site condition. The South Star I and II facilities are mostly located on soils and poorly consolidated sediments (Tulare Formation, Quaternary) and therefore , the ground motions will be modified by the site response of these soils.

To satisfy the requirements of CDMG for a quantification of the probabilistic ground shaking hazard at the site (CDMG, 2000), a site-specific probabilistic seismic hazard analysis has been performed. The objective of the CDMG requirement is to insure that a code-based seismic design of the facilities is adequate. The Uniform Building Code (1997) provides the seismic standard specified by the California Energy Commission (California Energy Commission, 1989) for non-nuclear plants such as the South Star I and II Project sites. Under the criteria of the code, the entire project area is within Seismic Zone 4 and, therefore, will have a seismic coefficient of 0.4. The probabilistic seismic hazard approach used in this study is based on the model developed principally by Cornell (1968). The calculations were carried out using the computer program HAZ20 developed by N. Abrahamson (consultant, written communication, 2000). The analysis consists of three stages: 1) characterization of seismic sources; 2) characterization of ground motion attenuation; and 3) estimation of the hazard.

Seismic source characterization is concerned with three fundamental elements: (1) the identification of significant sources of earthquakes; (2) the maximum size of these earthquakes; and (3) the rate at which they occur. Two types of earthquake sources are characterized in probabilistic seismic hazard analysis: (1) fault sources and (2) areal source zones. Significant faults in the site region (generally within 100 km (62 mi)) were characterized for input into the hazard analysis. Fault sources are modeled as three-dimensional fault surfaces and details of their behavior are incorporated into the source characterization. Areal source zones were used to represent background seismicity (events that cannot be associated with known faults but are occurring on buried faults). Areal sources are regions where earthquakes are assumed to occur randomly. Seismic sources are modeled in the hazard analysis in terms of geometry and earthquake recurrence.

The geometric source parameters for faults include fault location, segmentation model, dip, and thickness of the seismogenic zone. The recurrence parameters include recurrence model, recurrence rate (slip rate or average recurrence interval for the maximum event), slope of the recurrence curve (*b*-value), and maximum magnitude. For areal source zones, only the areas, maximum magnitude, and recurrence parameters (based on the historical earthquake record) need to be defined. In this analysis, we included the significant faults shown on Figure 8.15-2.

Uncertainties in the source parameters are included in the hazard model using logic trees. In the logic tree approach, discrete values of the source input parameters have been included along with our estimate of the likelihood that the discrete value represents the actual value.

To estimate the ground motions at a specified site as a result of the seismic sources considered in the probabilistic seismic hazard analysis, empirical attenuation relationships for spectral accelerations are used. The relationships used in this study were selected on the basis of the appropriateness of the site conditions and tectonic environment for which they were developed. Most of the facilities are located on the Tulare Formation so a stiff soil site condition was assumed appropriate.

The uncertainty in ground motion attenuation was included in the probabilistic analysis by using the log-normal distribution about the median values as defined by the standard error associated with each attenuation relationship. The same relationships used in the MCE ground motion calculations were used in the probabilistic analysis including those of Boore *et al.* (1997), Abrahamson and Silva (1997), Campbell (1997), and Sadigh *et al*. (1997). These were weighted equally in the analysis.

Based on the probabilistic seismic hazard analysis, a set of hazard curves, which display ground motion parameters (e.g., peak horizontal acceleration) as a function of annual exceedance probability (or return period) and Uniform Hazard Spectra (UHS) are computed. For a 10% exceedance probability in 50 years, the peak horizontal acceleration is 0.57. This spectrum is compared with the UBC spectrum for Seismic Zone 4. Also plotted are the 500-year spectral values from the National Hazard Maps.

8.15.2.3 Liquefaction and Lateral Spreading

Liquefaction is the phenomenon during which loose, saturated, cohesionless soils temporarily lose shear strength during strong ground shaking. Significant factors known to affect the liquefaction potential of soils are the characteristics of the material such as grain size distribution, relative density, degree of saturation, the initial stresses acting on the soils, and the characteristics of the earthquake, such as the intensity and duration of the ground shaking. Under conditions of liquefaction, granular materials lose all bearing capacity and become fluid-like.

It is not known whether the soils in the region of the site are susceptible to liquefaction. This can only be determined by site-specific geotechnical studies. However, for liquefaction to occur, the soils must be saturated. The groundwater table in the area is 91 m (300 ft) bgs, and no permanent surface water exists in the drainage creek close to the site. Therefore, the hazard for liquefaction and lateral spreading is considered low.

8.15.2.4 Slope Stability

Most of the facilities of the South Star I and II Project sites will be located on a moderate to relatively gently sloping area receiving only 152 to 203 mm (6-8 inches) of moisture per year indicating that the hazard from slope instability is negligible. However, the proposed transmission line route runs in a terrain which consists of steep rolling hills, most of which drop very steeply to narrow, deeply cut drainages, which are sandy and often highly eroded as the result of seasonal flooding. Engineering control to prevent further erosion and potential landslide shall be adopted for the transmission line route.

8.15.2.5 Erosion

The site topography and the occurrence of drop very steeply to narrow, deeply cut drainages, suggest erosion embankment is occurring during water run-off and seasonal flooding. A hazard from erosion exists but will be minimized by stabilization of constructed or disturbed surfaces (for example by compaction of soils and grading the surface for better drainage).

8.15.2.6 Subsidence

Land surface subsidence can result from both natural and man-made phenomena. Natural phenomena include subsidence resulting from tectonic deformations and seismically induced settlements; soil subsidence due to consolidation, hydrocompaction, or rapid sedimentation; subsidence due to oxidation or dewatering of organic-rich soils; and subsidence related to subsurface cavities. Subsidence or settlement related to human activities can be caused by a decrease in pore pressure due to the withdrawal of subsurface fluid, including water and hydrocarbons.

Ground subsidence is a relatively common phenomenon in the San Joaquin Valley and arises from a number of conditions, both tectonic and non-tectonic. Regionally, subsidence occurs as an isostatic response to sediment loading within the valley. This occurs over geologic time scales and is therefore not considered a hazard over the lifetime of the project. On a more local scale, there are a number of mechanisms leading to subsidence: pore-space collapse resulting from oil and gas extraction; subsidence due to groundwater removal; and hydrocompaction of aerated soils due to wetting. About 13,500 km^2 of the San

Joaquin Valley has subsided more than 24 cm (0.8 ft) since the 1920's, mainly as a result of overpumping of groundwater. In some areas, the amount of subsidence measures up to 9 m (29.5 ft) (Holzer, 1980). Overpumping of groundwater aquifers, in addition to petroleum extraction, has led to triggering of movement on surface-rupturing faults such as the Pond, Kern Front, Premier, and New Hope faults. Subsidence may also arise as a result of regional excursions in the water table due to tectonic strain changes (Muir Wood and King, 1993).

The South Star I and II Project sites area hydro-compaction and subsidence will not occur as a result of project activities because large volumes of water or steam will not be released to the naturally dry surface or near surface environment and withdrawals of groundwater are not anticipated for the project. Therefore, the potential for subsidence at the project site is low. However, if changes in water, or steam use are made during project development, subsidence impact will have to be reevaluated.

8.15.2.7 Expansive Soils

Certain soils, especially those containing smectite, mixed-layer clay, have the ability to shrink and swell depending on the moisture content of the soil. While the soils are wet, the smectite crystal structure absorbs water, leading to expansion or swelling. This results in a rise in the ground surface. There do not appear to be any site-specific borehole logs, and without any subsurface information we cannot conclusively rule-out the low probability of expansive soils.

8.15.3 Mitigation Measures

Mitigation measures are necessary because of potential geologic hazards. Geologic hazards mitigation measures for the project are:

Geol – 1. Design the South Star I and II Project sites and associated linears to conform with UBC requirements for Seismic Zone 4 and an estimated peak ground acceleration value of 57.2%g.

Geol – 2. Perform geologic surveys along the selected route of the transmission lines to determine any impact of construction activities on geologic resources.

Geol - 3 Design the South Star I and II Project sites and associated linears to minimize landslide and erosion impact.

No mitigation measures are required for geologic resources because the South Star I and II Project sites will have no significant impacts on recreational, commercial, or scientific geologic resources. There would also be no cumulative impact on geologic resources from construction of both project sites.

8.15.4 Proposed Conditions of Certification

In order to ensure compliance with applicable LORS and/or to reduce potentially significant impacts to less than significant levels, proposed conditions of certification are contained in Appendix K.

8.15.5 Laws, Ordinances, Regulations, and Standards

The laws, ordinances, regulations, and standards (LORS) that apply to geologic resources and geologic hazards for the South Star Project are presented in Table 8.15-4. The LORS for state, and local authorities are listed. There are no federal LORS that apply.

8.15.6 Involved Agencies and Agency Contacts

Agency	Contact/Title	Telephone
Kern County Building Department 2700 “M” Street Bakersfield, CA 93301	Robert Sawyer/ Principal Building Inspector	(661) 862-8656
Kern County Planning Department 2700 “M” Street Bakersfield, CA 93301	Holly Nelson Planner	(661) 862 8641

8.15.7 Permits Required and Permit Schedule

No permit requirement specifically addressing geologic resources and hazards was identified.

8.15.8 References

Abrahamson, N.A. and Silva, W.J., 1997, Empirical response spectral attenuation relations for shallow crustal earthquakes: Seismological Research Letters, v. 68, p. 94-127.

Bartow, J.A., 1987, Cenozoic nonmarine sedimentation in the San Joaquin Basin, central California, *in* R.A. Ingersoll and W.G. Ernst (eds.), Cenozoic Basin Development of Coastal California: Prentice-Hall, New Jersey, p. 146-171.

Bawden, G.W., 2001, Source parameters for the 1952 Kern County earthquake, California: A join inversion of leveling and triangulation observations: Journal of Geophysical Research, v. 106, p. 771-785.

Bloch, R.B., von Huene, R., Hart, P.E., and Wentworth, C.M., 1993, Style and magnitude of tectonic shortening normal to the San Andreas fault across Pyramid Hills and Kettleman Hills South Dome, California: Geological Society of America Bulletin, v. 105, p. 464-478.

Boore, D.M., and W.B. Joyner, T.E. Fumal, 1997, Equations for estimating horizontal response spectra and peak acceleration from western North America earthquakes: a summary of recent work: Seismological Research Letters, v.68, p.128-153.

California Energy Commission, 1989. Recommended Seismic Design Criteria for Non-nuclear Power Generating Facilities in California.

Campbell, K.W., 1997, Empirical near-source attenuation relationships for horizontal and vertical components of peak ground acceleration, peak ground velocity, and pseudo-absolute acceleration response spectra: Seismological Research Letters, v. 68, p. 154-179.

Castillo, D.A. and Zoback M.D., 1994, Systematic variations in stress state in the southern San Joaquin Valley: Inferences based on well-bore data and contemporary seismicity: American Association of Petroleum Geologists Bulletin, v. 78, p.1,257-1,275.

California Division of Mines and Geoloy (CDMG), 1964. Geologic map of California, Bakersfield sheet. Scale 1:250,000. Department of Conservation.

CDOG, 1999. California Division of Oil, Gas and geothermal resources, California Department of Conservation. 1999 Annual Report of the State Oil & Gas Supervisor.

CDOG, 2001. Oil, Gas, and Geothermal Fields in California, California Division of Oil and Gas, California Department of Conservation 2001, map at 1:1,500,000.

California Energy Commission, 1989. Recommended Seismic Design Criteria for Non-Nuclear Power Generating Facilities in California. Consultant Report N^{o} 700-87-005.

Dibblee, T. W., Sr. 1971. Geologic map of “Fellows” quadrangle, California. Open File Map. 1:62,500 scale.

Dickinson, W.R., 1981, Plate tectonics and the continental margin of California, *in* W.G. Ernst (ed.), The Geotectonic Development of California: Prentice Hall, p. 1-28.

Eaton, J.P. 1990. Earthquake and its aftershocks from May 2 through September 30, 1983, *in* Rymer, M.J., and W. L. Ellsworth, (eds), The Coalinga, California Earthquake of May 2, 1983: U.S. Geological Survey Professional Paper 1487, p.113-170.

Ellsworth, W.L. 1990. Earthquake history, 1769-1989, *in* Wallace, R.E. (ed), The San Andreas Fault System, California, U.S. Geological Survey Professional Paper 1515, p. 153-187.

Frankel A., Mueller C., Barnhard T., Perkins D., Leyendecker E.V., Dickman N. Hanson S., Hooper M., 1997. U.S. Department of the interior U.S. Geological Survey. National Seismic Hazard Maps, June 1996. Open File report 96-532.

Grant, L.B. and Sieh, K.E., 1993, Stratigraphic evidence for 7 meters of dextral slip on the San Andreas fault during the 1857 earthquake in the Carrizo Plain: Bulletin of the Seismological Society of America, v. 83, p. 619-635.

Grant, L.B. and Sieh, K., 1994, Paleoseismic evidence of clustered earthquakes on the San Andreas fault in the Carrizo Plain, California: Journal of Geophysical Research, v. 99B, p. 6,819-6,841.

Harden, D.R., 1998, California Geology: Prentice Hall, 479 p.

Hart, E.W., 1994, Fault-rupture hazard zones in California, Alquist-Priolo Earthquake Fault Zoning Act with index to Earthquake Fault Zones maps: California Division of Mines and Geology, Special Publication 42, 33 p.

Hill, D. P., Eaton, J. P., Ellsworth, W. L., Cockerham, R. S., Lester, F. W., and Corbett, E. J., 1991, The seismotectonic fabric of central California, *in* Slemmons, D. B., Engdahl, E. R., Zoback, M. R., and Blackwell, D. D. (eds.), Neotectonics of North America, Decade of North American Geology: Geological Society of America, p. 107-132.

Holzer, T.L., 1980, Faulting caused by groundwater level declines, San Joaquin Valley, California: Water Resources Research, v. 16, p. 1,065-1,070.

Jennings, C.W., 1994, Fault activity map of California and adjacent areas: California Division of Mines and Geology, California Geologic Data Map Series, Map No. 6, 1:750,000 scale.

Jones, L.M. and Dollar, R.S., 1986, Evidence of Basin-and-Range extensional tectonics in the Sierra Nevada: The Durrwood Meadows swarm, Tulare County, California (1983-1984): Bulletin of the Seismological Society of America, v. 76, p. 439-461.

Kern County Seismic Hazard Atlas (1975). Kern Council Government.

Medwedeff, D.A., 1989, Growth fault-bend folding at southeast Lost Hills, San Joaquin Valley, California: Bulletin of the American Association of Petroleum Geologists, v. 73, p. 54-67.

Muir Wood, R. and King, G.C.P., 1993, Hydrological signatures of earthquake strain: Journal of Geophysical Research, v. 98, p. 22,035-22,068.

Nelson, H, 2001. Kern County Planning Department, personal communication.

Norris, R.M. and Webb, R.W., 1990, Geology of California: John Wiley & Sons, New York, 541 p.

Page, R.W. 1986. Geology of the Fresh Ground-Water Basin of the Central Valley, California, with Texture Maps and Section: U.S. Geological Survey Professional Paper 1401-C, 54 p.

Perkins, J.A., 1987, Provenance of the Upper Miocene and Pliocene Etchegoin Formation: Implications for paleogeography of the Late Miocene of Central California: Unpublished MS thesis, San Jose State University, 110 p.

Real, C.R., Toppozada T.R., and Parke, D.L., 1978, Earthquake catalog of California, January 1, 1900-December 31, 1974: California Division of Mines and Geology Special Publication 52.

Richter, C.F., 1955, Foreshocks and aftershocks, *in* G.B. Oakeshott (ed.), Earthquakes in Kern County California During 1952: California Division of Mines and Geology Bulletin 171, p. 177-198.

Sadigh, K., Chang, C.Y., Egan, J.A., Makdisi, F., and Youngs, R.R., 1997, Attenuation relationships for shallow crustal earthquakes based on California strong motion data: Seismological Research Letters, v. 68, p. 180-189.

Sieh, K.E., 1978, Slip along the San Andreas fault associated with the great 1857 earthquake: Bulletin of the Seismological Society of America, v. 68, p. 1,421-1,448.

Stover, C.W. and Coffman, J.L., 1993, Seismicity of the United States, 1568-1989 (revised): U.S. Geological Survey Professional Paper 1527, 418 p.

Toppozada, T.R., Real, C.R., and Parke, D.L., 1981, Preparation of isoseismal maps and summaries of reported effects for pre-1900 California earthquakes: California Division of Mines and Geology Open-File Report 81-11, 181 p.

Townley, S.D. and Allen, M.W., 1939, Descriptive catalog of earthquakes of the Pacific Coast of the United States 1769 to 1928: Bulletin of the Seismological Society of America, v. 29, 297 p.

UBC, 1997. Uniform Building Code, Volume 2. Structural Engineering Design Provisions.

USGS, 2000. Information obtained from the U.S. Geological Survey website at http://eqint.cr.usgs.gov/eq/

USGS, 2000b. Information obtained from the U.S. Geological Survey website at http://ca.water.usgs.gov//gwatlas/valley/landsub.html.

Wakabayashi, J. and Smith, D.L., 1994, Evaluation of recurrence intervals, characteristic earthquakes and slip-rates associated with thrusting along the Coast Range-Central Valley geomorphic boundary: Bulletin of the Seismological Society of America, v. 84, p. 1,960-1,970.

Warne, A.H., 1955, Ground fracture patterns in the southern San Joaquin Valley resulting from the Arvin-Tehachapi earthquake, *in* G.B. Oakeshott (ed.), Earthquakes in Kern County California During 1952: California Division of Mines and Geology Bulletin 171, p. 57-66.

Wells, D.L. and Coppersmith, K.J., 1994, New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement: Bulletin of the Seismological Society of America, v. 84, p. 974-1002.

Wong, I.G. and Ely, R., 1983, Historical seismicity and tectonics of the Coast Ranges-Sierran Block boundary: Implications to the 1983 Coalinga, California earthquakes, *in* [J. Bennett and R. Sherburne (eds.)] The 1983 Coalinga Earthquakes: California Division of Mines and Geology Special Publication 66, p. 89-104.

Wong, I.G., Ely, R.W., and Kollmann, A.C., 1988, Contemporary seismicity and tectonics of the Northern and Central Coast Ranges-Sierran Block Boundary zone, California: Journal of Geophysical Research, v. 93, p. 7,813-7,833.

Working Group for California Earthquake Probabilities, 1995, Seismic hazards in southern California: Probable earthquakes, 1994 to 2024: Bulletin of the Seismological Society of America, v. 85, p. 379-439.

Working Group on Northern California Earthquake Potential, 1996, Database of potential sources for earthquakes larger than magnitude 6 in northern California: U.S. Geological Survey Open-File Report 96-705, 53 p.

Table 8.15-1. MCE Median (50th percentile) Peak Horizontal Accelerations On Soil

Seismic Source	MCE (M)	Fault Style[1]	Distances (km) Horizontal[2]	Rupture[3]	Seismogenic[4]	Peak Horizontal Acceleration (g's) Abrahamson & Silva (1997)	Campbell (1997)	Sadigh et al. (1997)	Boore et al. (1997)	Weighted Average PGA
San Andreas Fault	8.0	S	11.3	11.3	11.5	0.45	0.48	0.39	0.51	0.43
White Wolf Fault	7.8	R	72.4	72.4	73.6	0.12	0.10	0.12	0.13	0.12
Pleito Fault Zone	7.5	R	33.8	33.8	39.3	0.18	0.17	0.22	0.21	0.19
Garlock Fault	7.4	S	69.2	69.2	69.2	0.08	0.08	0.08	0.10	0.08
San Gabriel Fault	7.0	S	78.9	78.9	78.9	0.06	0.05	0.05	0.07	0.06
CRSB	6.5	R	12.0	12.0	12.2	0.29	0.34	0.31	0.26	0.30

[1] N = Normal Slip, S = Strike Slip, R = Reverse Slip
[2] Horizontal distance is defined as the shortest distance from the site to the vertical projection of the fault rupture on the earth's surface.
[3] Rupture distance is the shortest distance from the site to the surface rupture.
[3]Seismogenic distance is the shortest distance from the site to the zone of seismogenic rupture. The top of this zone is assumed to be at a depth of 2 km.

Table 8.15-2. Abridged Modified Mercalli Intensity Scale

I	Not felt except by a few under especially favorable circumstances (RF* I)
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (RF I to II)
III	Felt quite noticeably indoors, especially on upper floor of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated. (RF III)
IV	Felt indoors by many, outdoors by few during the day. Some awakened at night. Dishes, windows, door disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. (RF IV to V).
V	Felt by nearly everyone, many awakened. Some dishes, windows, and other fragile objects broken; cracked plaster in a few places; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (RF V to VI)
VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster and damaged chimneys. Damage slight. (RF VI to VII)
VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving cars. (RF VIII)
VIII	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel wall thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water levels. Persons driving cars disturbed. (RF VIII + to IX)
IX	Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings; with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (RF IX +)
X	Some well built structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed, slopped over banks. (RF X)
XI	Few, if any, [masonry] structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII	Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into the air.

* Equivalent Rossi-Forel (RF) intensities.

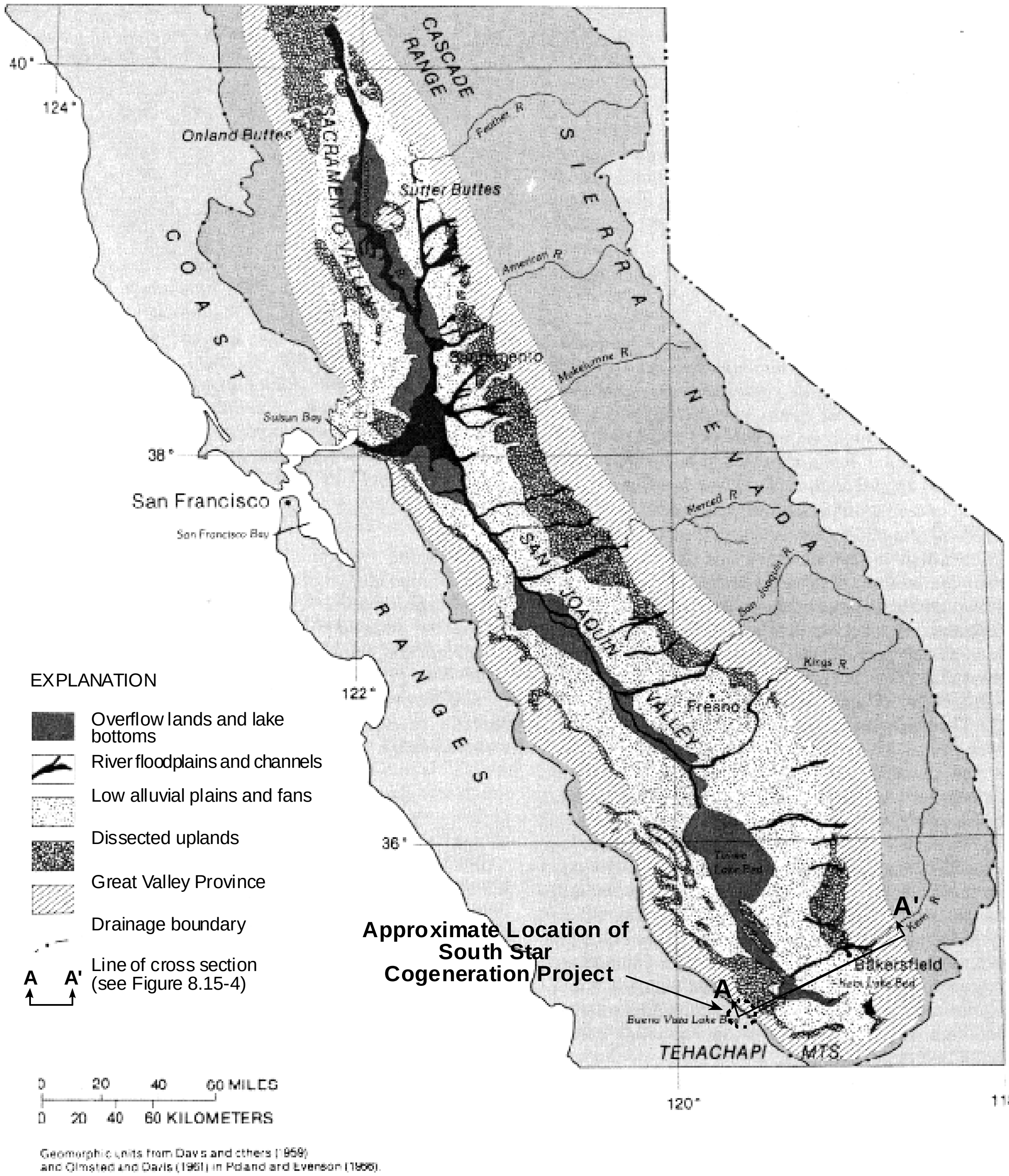
Table 8.15-3. Calculated Peak Ground Acceleration (PGA) with 10% Probability of Exceedance in 50 Years South Star I and II Project Sites

Locations	Lat/Lon	PGA (g)
Cogen plant South Star I	35.1/-119.52	0.57
Cogen plant South Star II	35.2/-119.54	0.40
Transmission line	39.20/-119.58	0.52
	35.17/-119.57	0.52
	35.14/-119.53	0.57
Proposed Natural Gas Line	35.17/-119.51	0.40
	35.18/-119.48	0.40

Source: USGS, 2000.

Table 8.15-4. Laws, Ordinances, Regulations, and Standards for Geologic Resources and Hazards

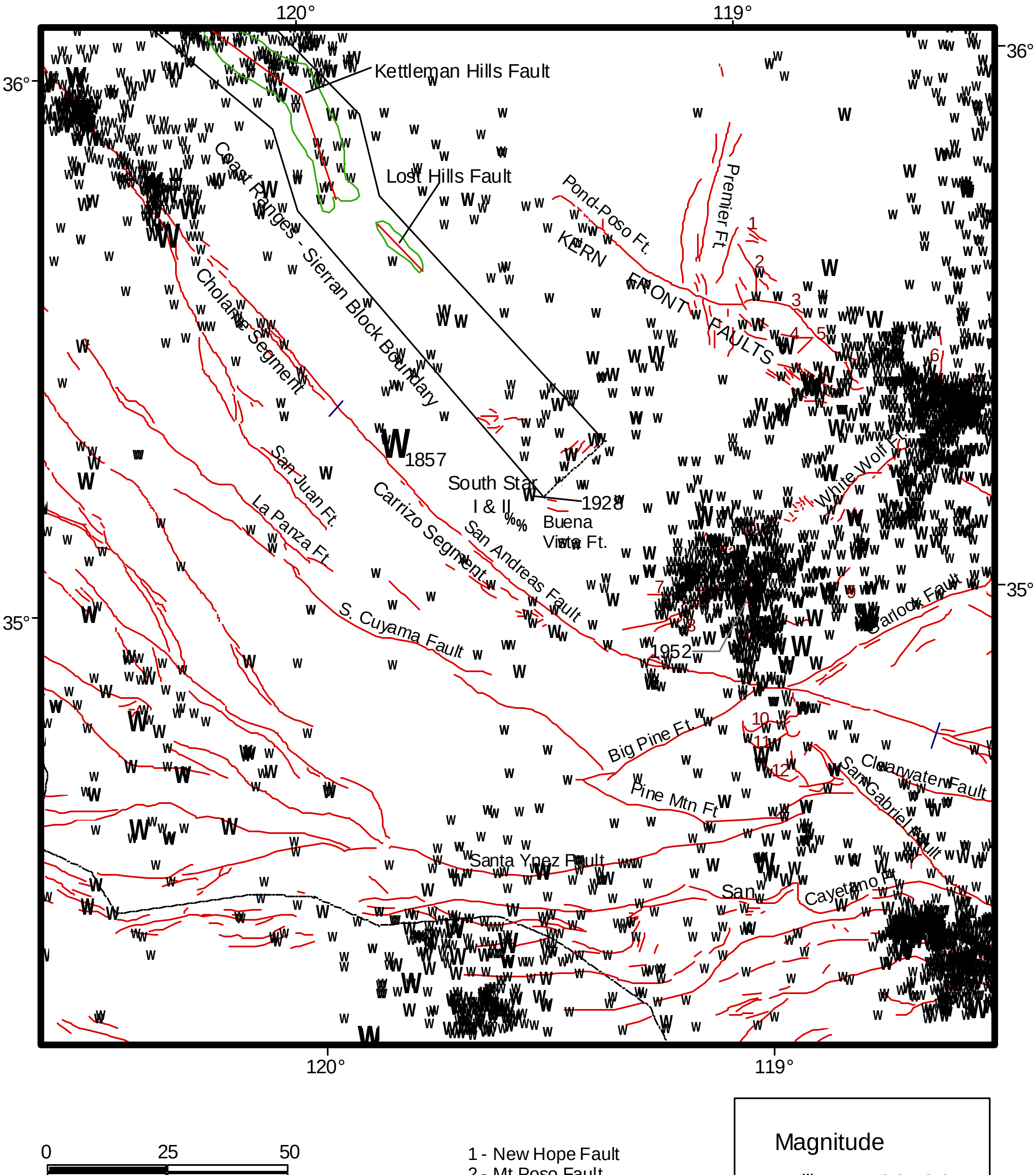
Jurisdiction	Authority	Administering Agency	AFC Conformance Section
Federal	None applicable	—	—
State	California Public Resources Code § 25523(a); CCR §§ 1752(b) and (c).	Kern County Building Department	Compliance with this regulation is discussed in 8.15.1.4.
	Alquist-Priolo Earthquake Fault zoning Act (1994 rev).		
Local	Uniform Building Code (UBC), 1997. Appendix Chapter 16, Division 4.	Kern County Building Department	Compliance with this code is discussed in 8.15.2.1.
Industry	Structural and Seismic Design Criteria in Work Description	None	Compliance with this standard is discussed in 8.15.2.



Source: Page, 1986

URS	Project No. 51-00167034.00 South Star Cogeneration Project	GEOMORPHIC FEATURES OF THE SOUTH STAR I AND II COGENERATION PROJECT AREA	Figure 8.15-1

51-00167034.00-00017/071301/gos

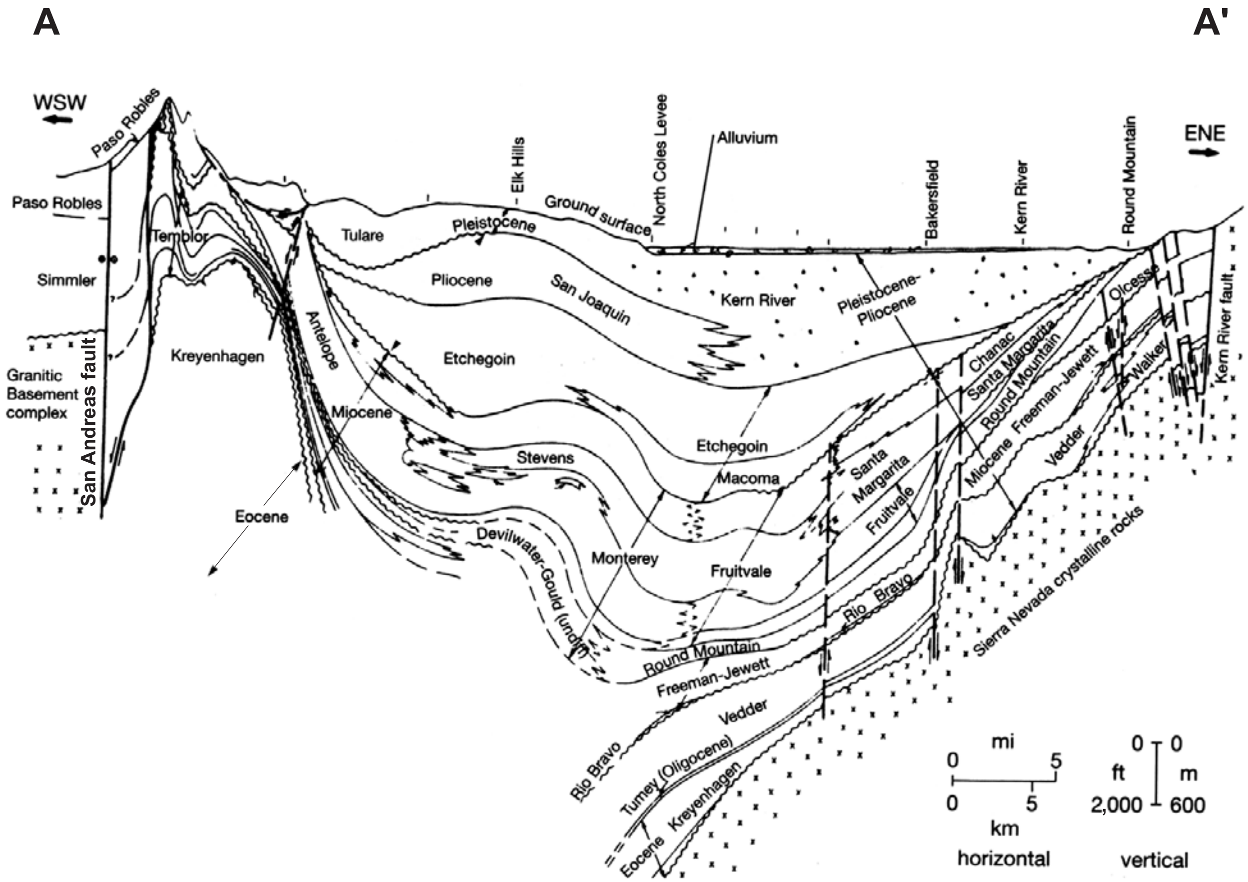


1 - New Hope Fault
2 - Mt Poso Fault
3 - Poso Creek
4 - Jewett Fault
5 - Kern Gorge Fault
6 - Breckenridge Fault
7 - Wheeler Ridge Fault
8 - Pleito Fault
9 - Springs Fault
10 - Frazier Mtn Thrusts
11 - Dry Creek Thrusts
12 - Alamo Thrusts

Note: Southern extent of Coast Ranges - Sierran Block Boundary is not well defined.

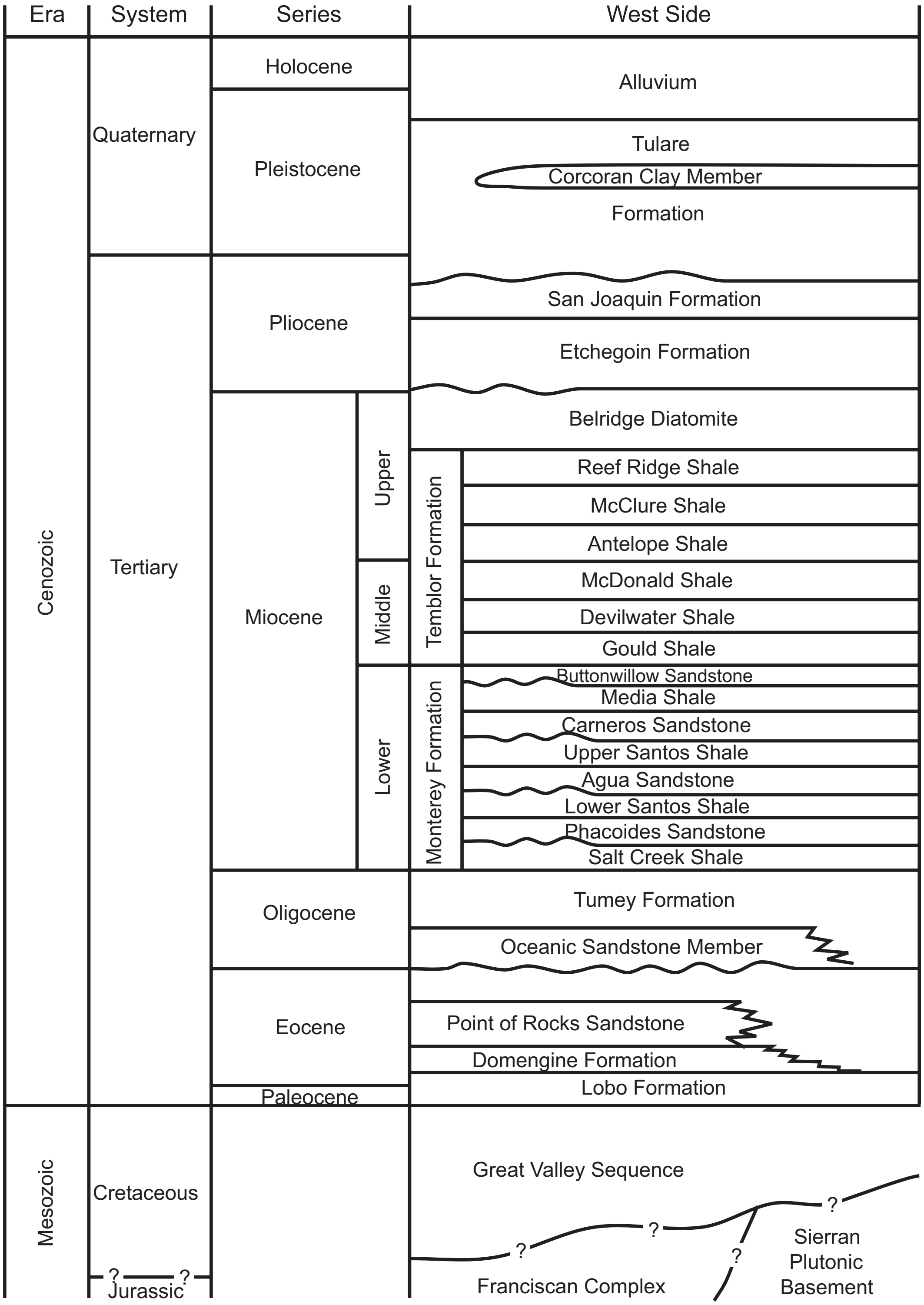
Magnitude	
w	3.0 - 3.9
w	4.0 - 4.9
W	5.0 - 5.9
W	6.0 - 6.9
W	7.0 - 7.9
W	8.0 - 8.9

URS	Project No. 51-00167034.00	QUATERNARY FAULTS AND HISTORICAL SEISMICITY, 1852-2000, WITHIN 100 KM OF SOUTH STAR I AND II (M >=3.0)	Figure 8.15-2
	South Star Cogeneration Project		



SOURCE: Harden, 1998

URS	Project No. 51-00167034.00 South Star Cogeneration Project	SIMPLIFIED GEOLOGIC CROSS SECTION A-A', SAN ANDREAS FAULT TO KERN RIVER FAULT	Figure 8.15-3



SOURCE: Dibblee, 1973

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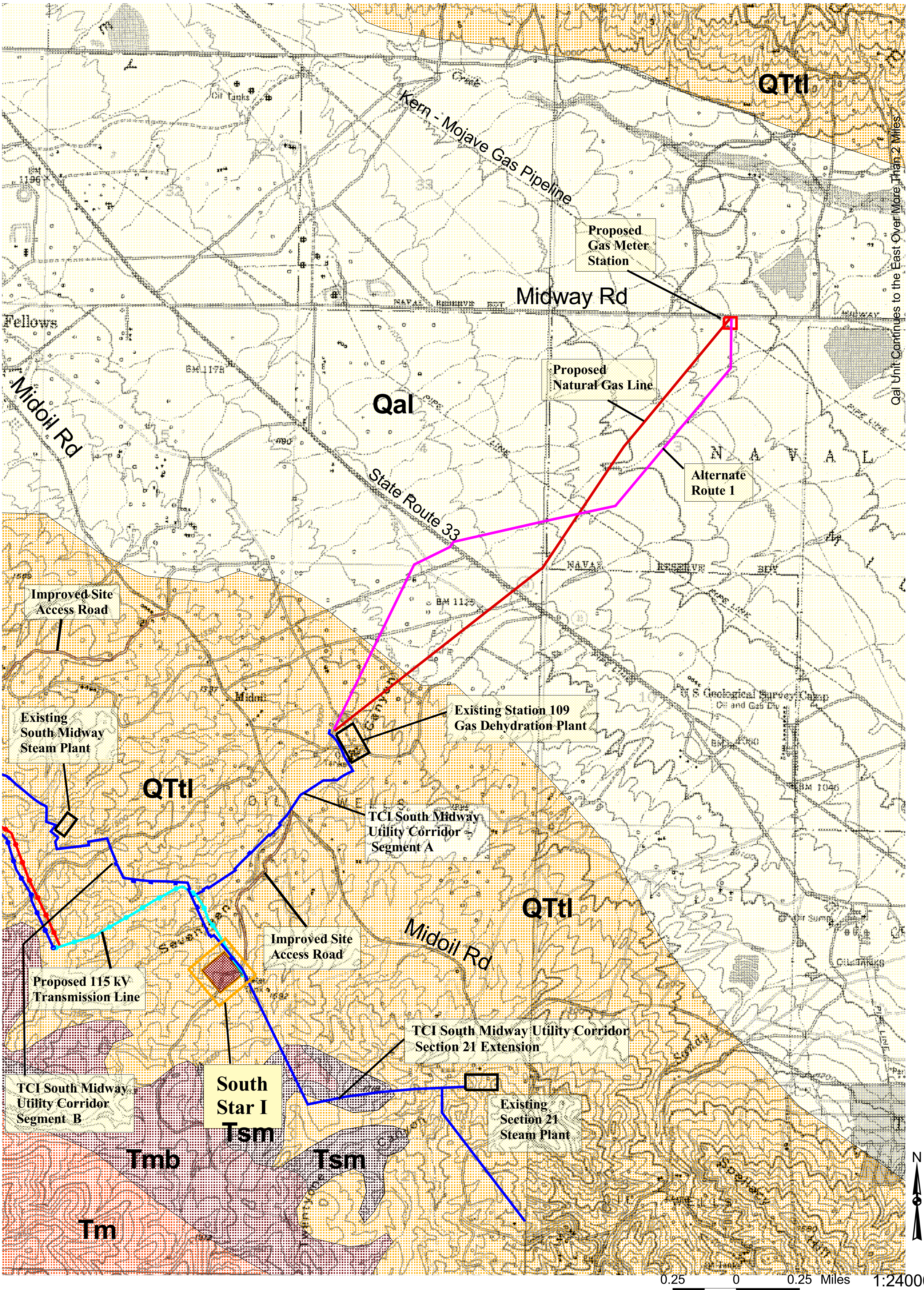
Project No. 51-00167034.00

Texaco South Star Cogeneration Project

GENERALIZED STRATIGRAPHIC COLUMN IN THE SOUTH STAR PROJECT AREA

Figure 8.15-4



- Alternate Route 2 (Natural Gas and Water Line)
- Alternate South Star II 115 kV Transmission Line
- Existing 12.47 kV Transmission Line (to be reconductored for 115 kV)
- Proposed 115 kV Transmission Line
- TC1 South Midway Utility Corridor (Segments A, B, C Natural Gas, Steam, & Water Lines)
- Site Boundaries
- Miscellaneous Facility

Quaternary	Plio-Pleistoene - Holocene	Qal: Alluvium
	Plio-Pleistoene	QTtl: Tulare Formation
Tertiary	Miocene	Tsm: Santa Margarita Formation
		Tmb: Monterey Shale Formation - Monterey Shale Member
		Tm: Monterey Shale Formation - McLure Shale Member
		Tmg: Monterey Shale Formation - Gould Shale Member
	Oligocene and Miocene	Ttm: Temblor Formation - Media Shale Member

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South Star Cogeneration Project

Project No. 51-00167034.00

Geological Map in the Project Area (Sheet 1 of 2)

Figure 8.15-5

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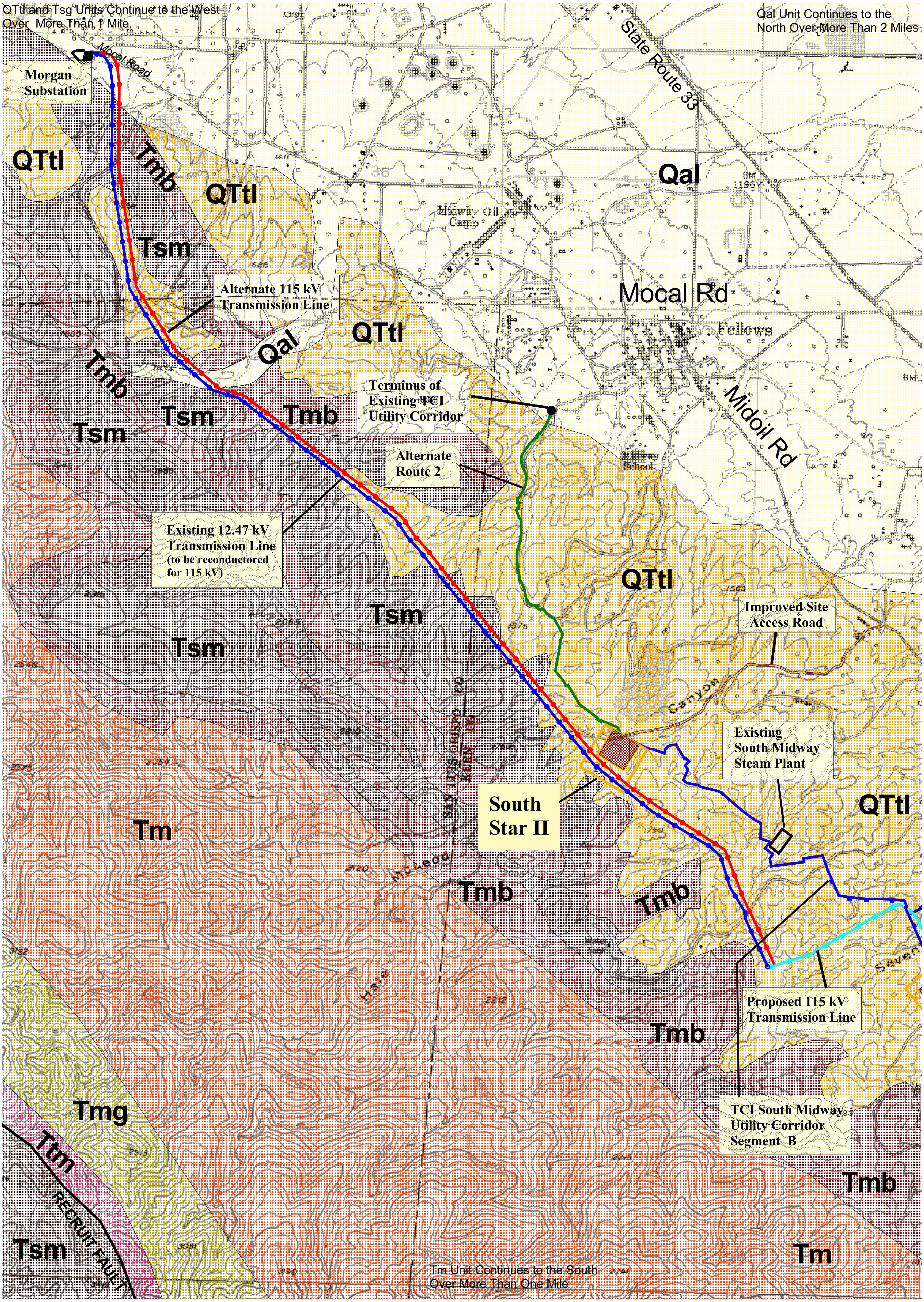

Alternate Route 1 (Natural Gas)
Existing 12.47 kV Transmission Line (to be reconductored for 115 kV)
Proposed 115 kV Transmission Line
Propsed Natural Gas Line (Approx. 10, 500 feet)
TC1 South Midway Utility Corridor
(Segments A, B, C Natural Gas, Steam, & Water Lines)
Site Boundaries
Miscellaneous Facility

Quaternary	Plio-Pleistoene - Holocene	Qal: Alluvium
	Plio-Pleistoene	QTtl: Tulare Formation
Tertiary	Miocene	Tsm: Santa Margarita Formation
		Tmb: Monterey Shale Formation - Monterey Shale Member
		Tm: Monterey Shale Formation - McLure Shale Member
		Tmg: Monterey Shale Formation - Gould Shale Member
	Oligocene and Miocene	Ttm: Temblor Formation - Media Shale Member

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South Star
Cogeneration Project

Project No. 51-00167034.00

Geological Map in the Project Area (Sheet 2 of 2)

Figure
8.15-5

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